SURVEY OF SENSOR PAYLOADS for UAVs

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Advanced Sensor Payloads for UAVs
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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

SURVEY of UAV SENSOR PAYLOADs

- **BACKGROUND on SURVEY**
- **EO/IR SENSORS**
  - **FLIR**
  - **IRST**
  - **Multi / Hyperspectral Infrared**
- **LASER SENSORS**
  - **LIDAR (soft targets)**
    - **Pollution Monitoring**
    - **Chem / Bio Sensors**
  - **LADAR (hard targets)**
    - **Obstacle Avoidance**
    - **Terrain Mapping**
- **RADAR SENSORS (MTI / SAR)**
  - **Surveillance & Reconnaisance**
  - **Targeting & Fire Control**
- **ELECTRONIC WARFARE SENSORS**
  - **Precision ESM Sensors**
  - **Missile Warning Receivers**
- **TARGET LOCATION ERROR (TLE)**
- **AUTOMATIC TARGET RECOGNITION / BDA**
- **SUMMARY**

Background on Survey

- Original surveys performed for Navy UAV Programs and summarized in CY2000 reports
- Types of information in each report
  - UAV sensor payloads (< 200 pounds)
  - Small UAV sensor payloads (<40 pounds)
- Presentation represents excerpts from reports
- Updated with new sensor payload information

FSI “Brite Star”

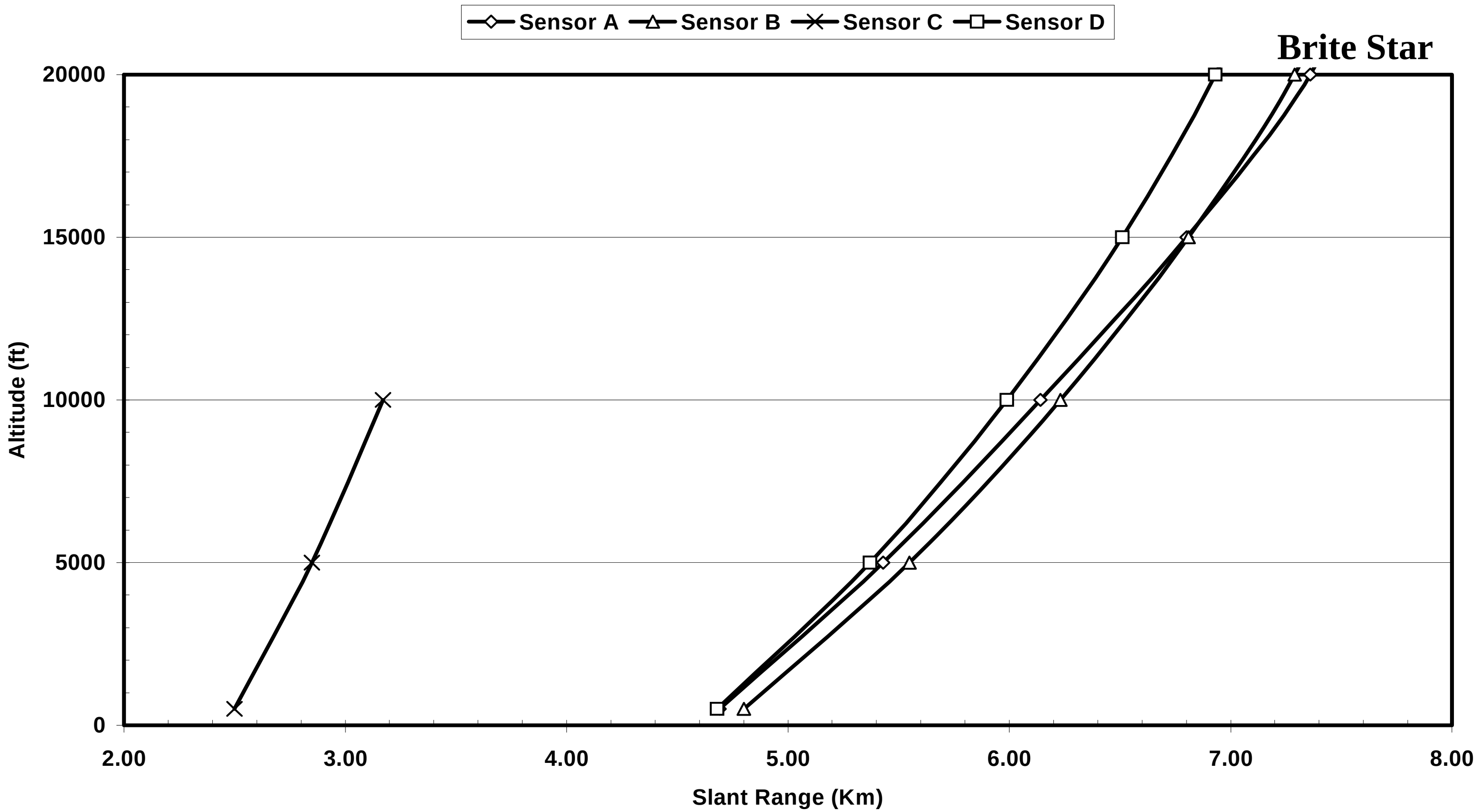
TABLE 4. Hypothetical MWIR 512 x 512-Element Staring FPA Sensor Design Parameters.

Parameter	Characteristic
Aperture diameter (cm)	15.24
Focal length (cm)	62.4
F/number	4.09
NFOV (mrad)	16.4
IFOV(mrad)	0.032
Noise equivalent temperature difference (NETD) (°C)	0.013
Detector integration time (ms)	16.5
Frame rate (Hz)	30
Noise bandwidth (Hz)	30.3
Nyquist frequency limit (cycles/mrad)	15.6
Magnification (with 12-in. display)	30

TABLE 5. Predicted Performance of a Hypothetical 512- by 512-Element Staring FPA System.

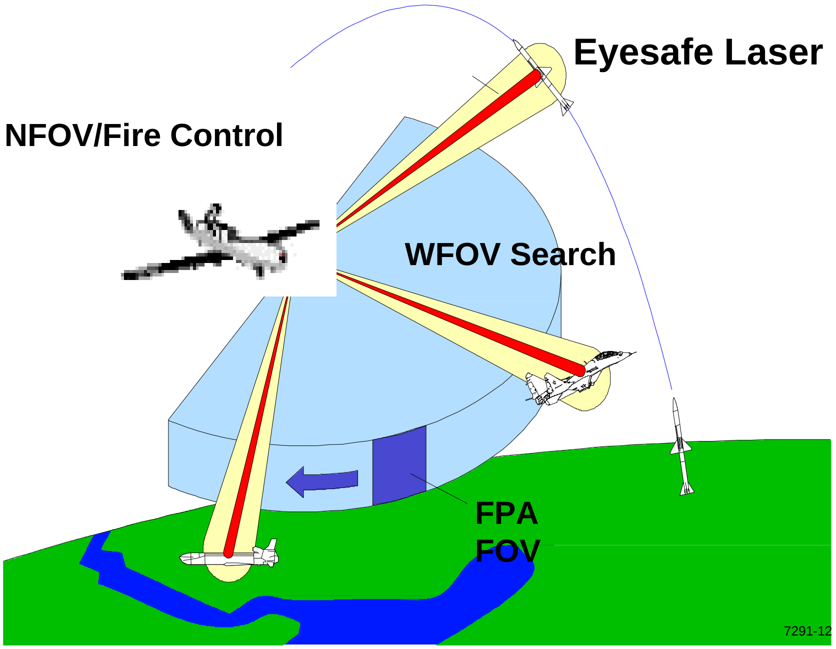
Discrimination level	Example	Slant range, km		
		Jitter = 10 μrad	Jitter = 20 μrad	Jitter = 30 μrad
Classification	Vehicle	18.6	15.7	13.1
Type recognition	Tracked vehicle	16.2	13.6	11.3
Recognition	Tank	12.8	10.7	8.8
Friend or foe	**Hostile tank**	9.1	7.5	6.1
ID	**Tank type**	***7.0***	***5.8***	***4.7***
Authentication	**Decoy Discrim.**	5.7	4.7	3.8
Positive ID	**Allegiance**	4.8	4.0	3.2

Fast Boat in Middle East MWIR ID(N95)*



- •ID(N95) – 95% of the Operators viewing the MWIR image will correctly identify (highest level of discrimination) this maritime target

UAV IRST MISSION & HARDWARE



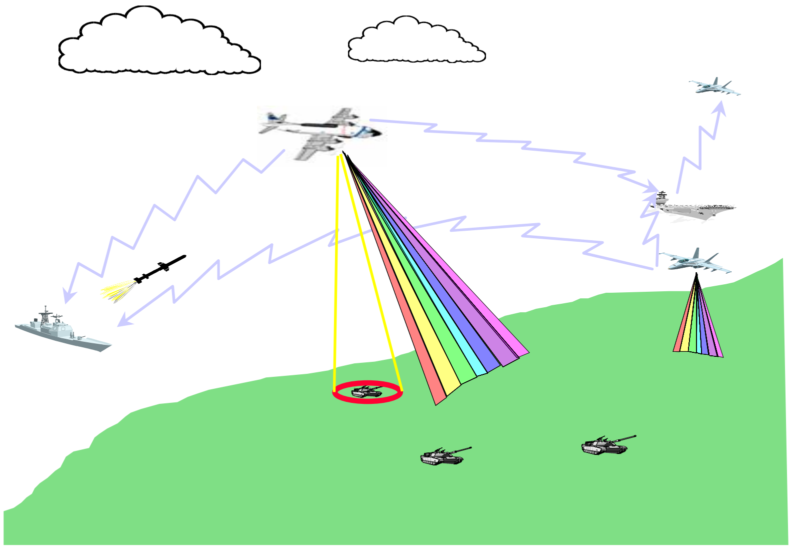
Weight (total)	**260.6 lbs**
Turret (with ELRF)	69 (121)
Controller	53
Processor	65
GPS/INS	21.6
Volume (total)	**7.2 cu. ft.**
Turret	1.6
Controller	1.5
Processor	3.7
GPS/INS	.4
Power (total)	**1774 watts**
Turret	580
Controller	214
Processor	750
GPS/INS	40
Performance	
FOR	90° EL x 165°AZ
FOV	3° x 3°(NFOV) 28° x 28° (WFOV)
IFOV	.10 mR (NFOV) 1.0 mR(WFOV)

UAV IRST FIRST FLIGHT

FEB. 2, 2000

- **INSTALLED ON CONVAIR 580 BASED IN Greenville, Texas**
- **BO2D TARGET AIRCRAFT**
- **COOPERATIVE PATTERNS**
  - **OVALS**
  - **FORMATION**
- **ELECTRO-MECHANICAL CHECKOUT @ 5000 ft.**
- **DEMONSTRATED**
  - **VIDEO TRACKER**
    - **WFOV**
    - **NFOV**
  - **DATA RECORDING**

Multispectral/Hyperspectral Imaging



◆Detection/identification of clear and partly concealed targets over large regions of the battlefield
- ❖Improved Battlefield/Situation Awareness
- ❖Onboard sensor data screening, reduced bandwidth
- ❖Rapid sensor-to-shooter cycle
- ❖Counter-CC&D

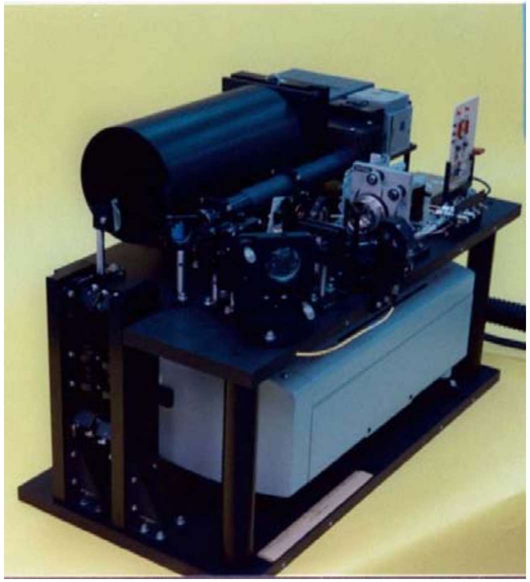
◆Technical Issues:
- ❖Spectral Band Choice
- ❖Spectral Analyzer Development
- ❖Algorithm Development
- ❖System Integration
- ❖Performance Demonstration

AISA AIRBORNE SENSOR

Chem / Bio Agent Detection with LIDAR

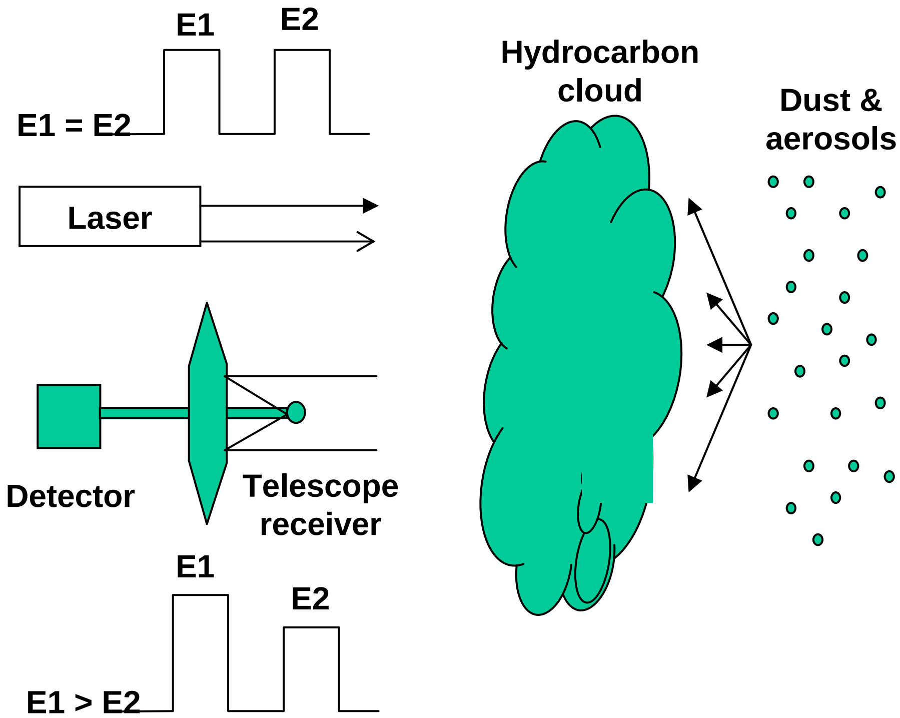
LIDAR

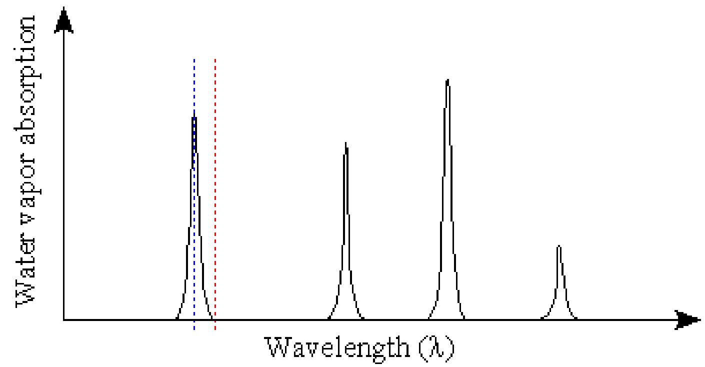
- Sensing of Atmospheric Aerosols
  - Pollution Monitoring
  - Chemical Agent Detection
  - Biological Agent Detection
- Airborne “Biological Agent Sensor”
  - Aerosol Spatial Distributions
  - Precise wind speed of aerosol cloud
  - Bio-material detection by fluorescent scattering
  - Flown on Queen Air in CY 2000
  - < 40 lb payload for UAV
- Differential Absorption LIDAR (DIAL)
  - Carbon Dioxide Laser for Long Wavelengths
  - Compact systems in development



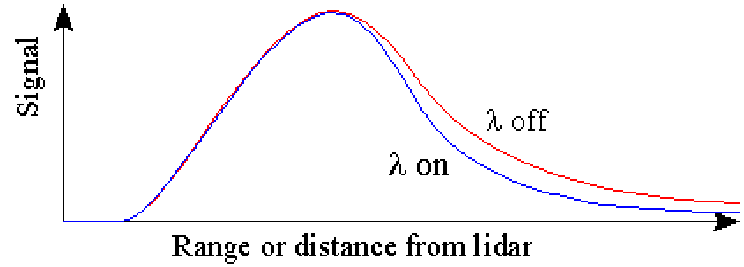
EOO Inc.

DIAL Chemical/Biological Agent Detection

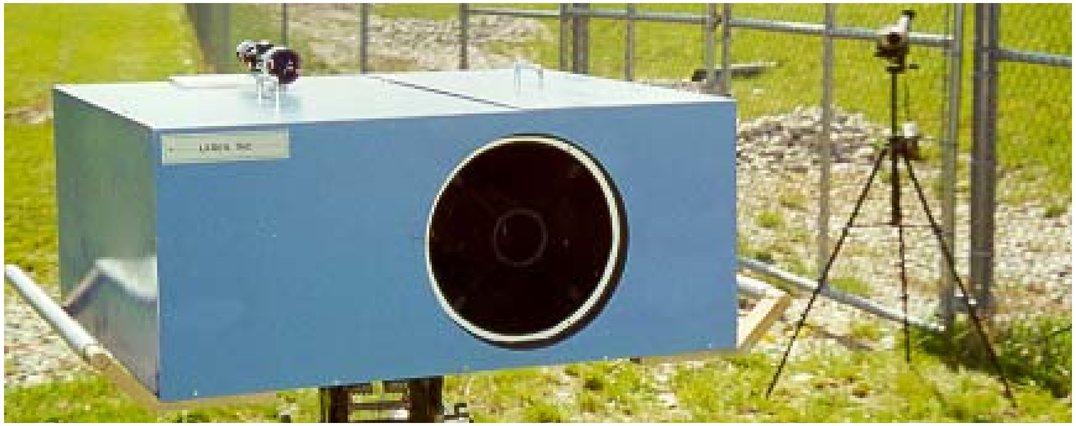




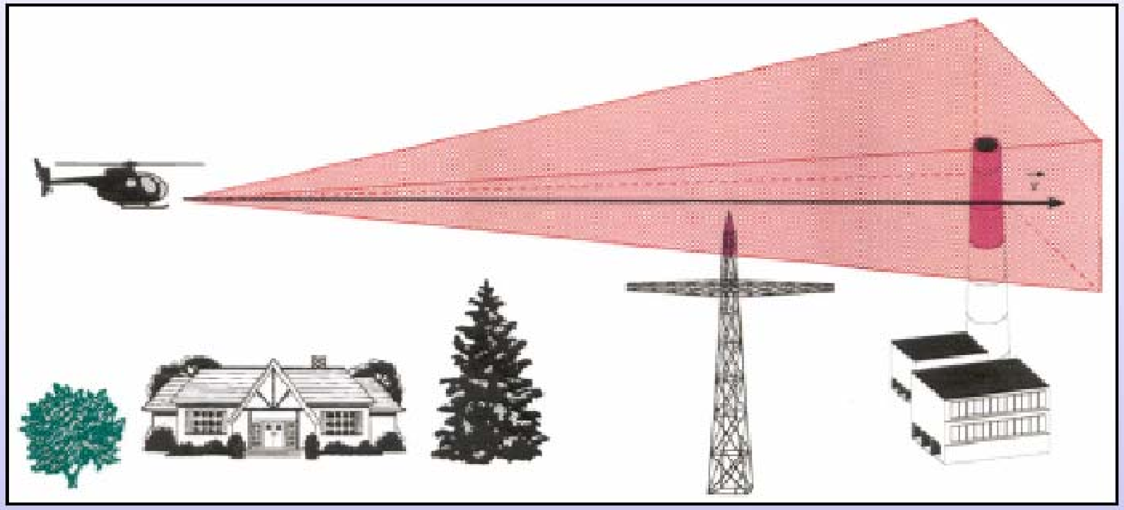
(a) Water vapor absorption spectrum



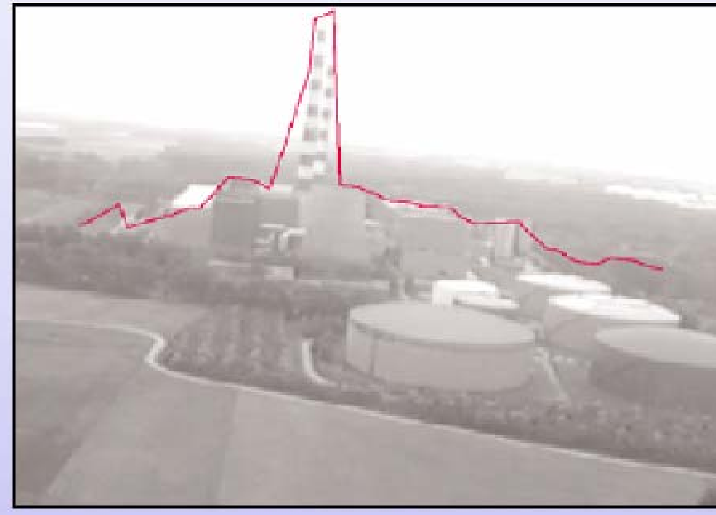
(b) Typical DIAL signals as a funtion of range



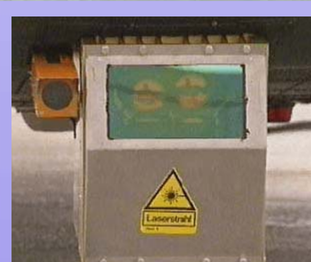
LADAR Obstacle Avoidance HELLAS (EADS)

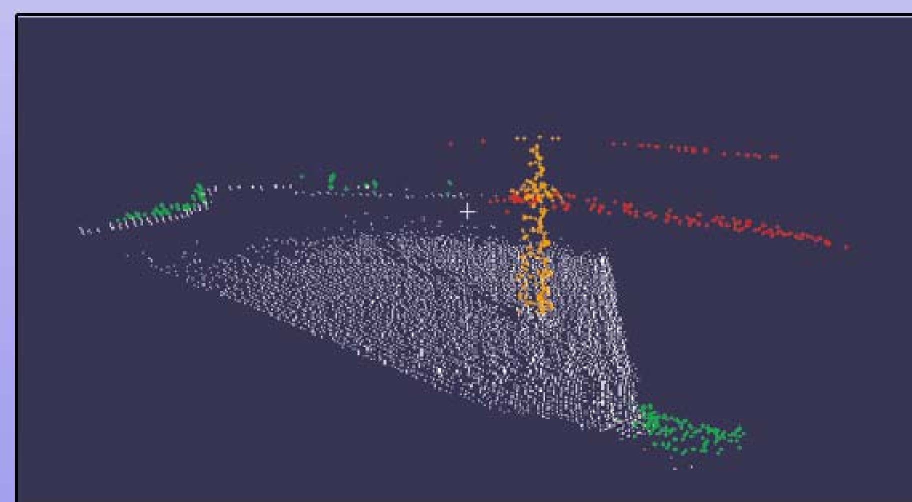


Collision Avoidance -- Tunnel

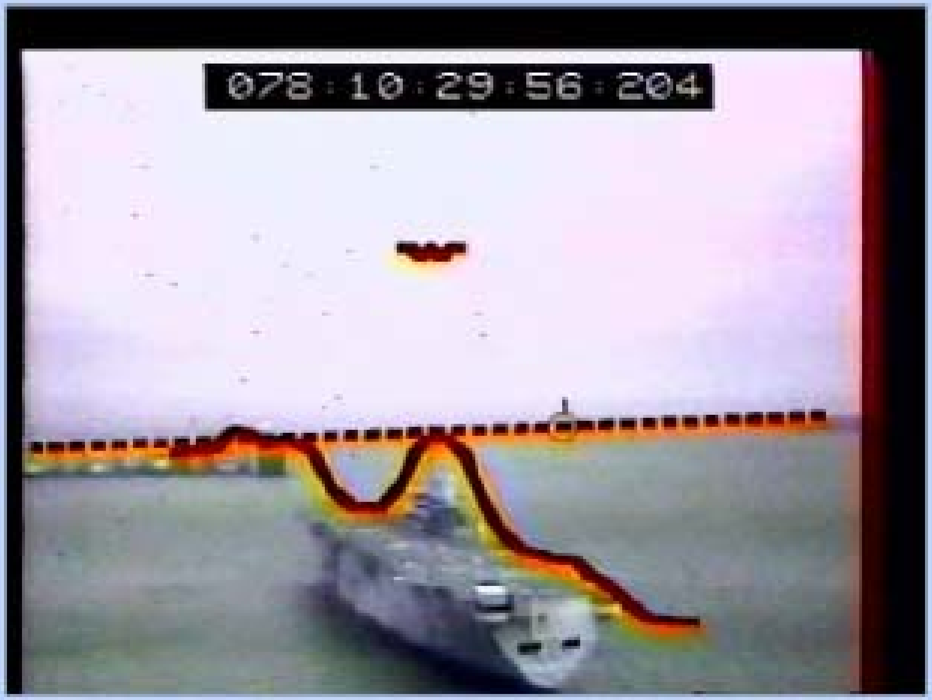


Safety Line

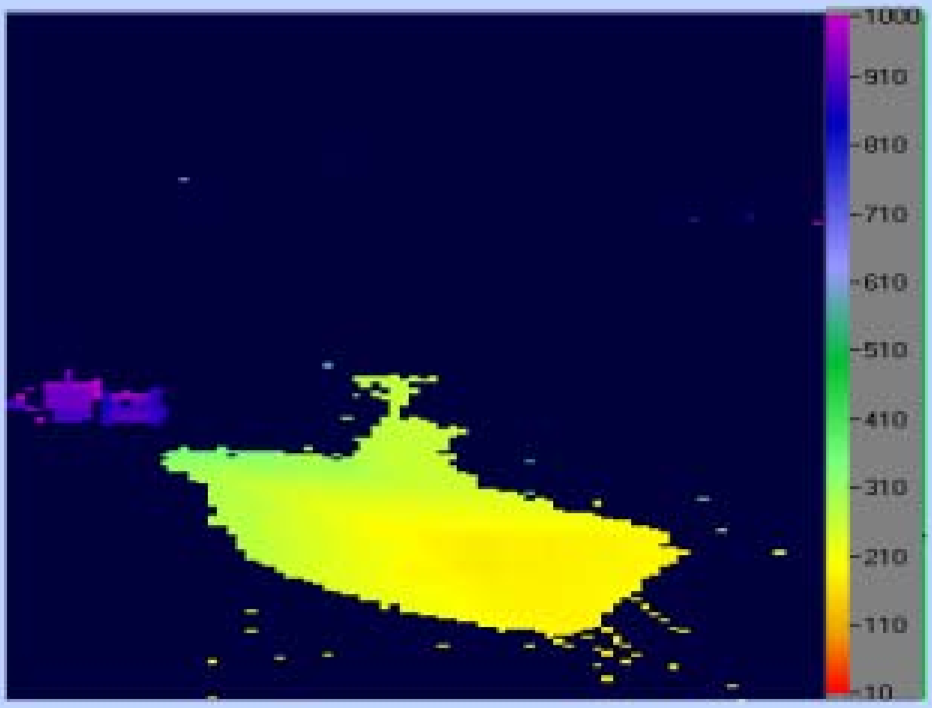




Flight 13 - (19 Mar 03)



Flight Video



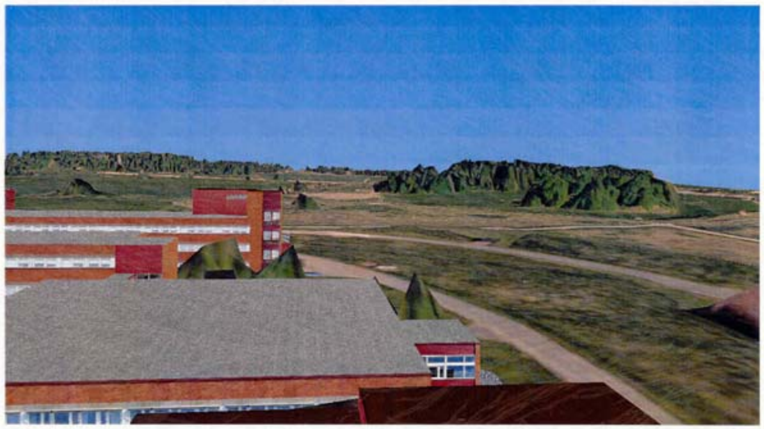
Hellas LADAR

EYESAFE LADAR @ 1.54 MICRON

Applications of 3-D Imaging LADAR

Terrain Mapping

FOA laser generated model



Scanning laser radar

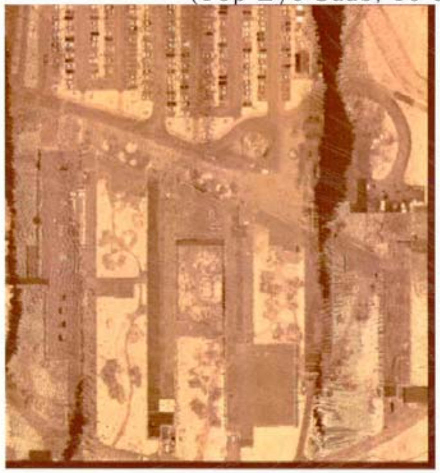
Top Eye,
derivative
from Hawk Eye

Topo needs only
1/1000
of
Pulse energy
cf underwater appl.

Swedish archipelago

Airborne laserradar

(Top Eye Saab, 10 cm avst.noggr.)



Intensitetsbild

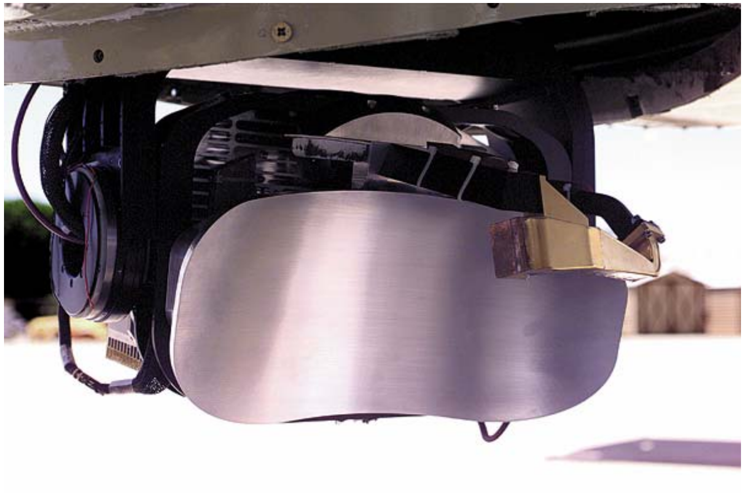
Höjdbild

Ex. of laser scanning of buildings

TABLE 16. Demonstrated UAV SAR Systems.

Radar system	LARGE (UAV System)	MEDIUM (UAV System)	SMALL (UAV System)
Operating frequency (GHz)	8.4 to 9.0	15.2 to 18.2	Exact freq. TBD
Stripmap Mode			
Range (km)	200	7 to 30	4.4 to 10.8
Resolution (m)	1.0	0.3 to 3.0	0.3
Ground swath (pixels)	TBD	2600	1000
View size (m)	TBD	934	~800
Squint angle (deg)	±45	± (45 to 135)	±45
Spotlight Mode			
Range (km)	200	4 to 25	4.4 to 10.9
Resolution (m)	0.3	0.1 to 3	0.3 to 1
Swath width (pixels)	TBD	2x(640x480)	1000
Depression angle (deg)	TBD	TBD	-10 to -60
Squint angle (deg)	±45	± (45 to 135)	±45
Peak side lobes (dB)	TBD	TBD	TBD
Dynamic range (dB)	TBD	>85	>75
Absolute RCS calibration, 3σ (dB)		TBD	<10
Weight (lb)	635	120	168
Circular error probability (CEP) (m)		< 4	< 25
Size (ft^3)	15	3	~2

Lynx SAR (AN/APY-8) – Ku-band Radar



Lynx SAR mounted on King Air

- **Developed by Sandia National Laboratories and General Atomics for UAV applications**
- **In Production at General Atomics**
  - **Installed on King Air, Predator, IGNAT, Black Hawk**
- **High-performance, multi-mode radar**
  - **SAR spotlight resolution – 0.3 m to 3 m**
  - **Strip-map resolution – 0.3 m to 3m**
  - **GMTI mode**
- **Extended-range operation**
  - **33 km for .3m resolution in weather**
  - **54 km for .3m resolution in clear air**
- **Low weight and power**
  - **115-lb total weight**
  - **<100-lb version developed**
  - **<1.2-kW prime power**

GENERAL ATOMICS

UAV Synthetic Aperture Radar (SAR)

MISSION: Provide Surveillance, Targeting and Battle Damage Assessment Capability that Penetrates Weather, Haze and Obscurants.

Example Current ATD (TUAVR)

Size: 1.2 cu. ft.
Weight: 65 lbs.
Range: 7-10 Km. most cond.
Resolution: 1.0 m, strip mode
0.3 m, spot mode
CEP: 25 m
Flight Test: 4th quart. FY00

Demonstration Goals by 2005*

Size: < 0.5 cu. ft.
Weight: < 20 lbs.
Range: 3 - 7 Km. in weather
7 - 10 Km. most conditions
Resolution: 0.3 - 1.0 m., strip mode
0.3 m., spot mode
CEP: < 10 m

*current programs

Maturing Critical Technologies

- Monolithic Microwave Integrated Circuits (MMIC's)
- Advanced Microwave Antenna Designs
- Multi-Resolution Signal Processing
- Computer Processing / Packaging
- Advanced Precision Navigation

Expected Advanced Capabilities by 2005*

- Reduced CEP
- Improved Ground Moving Target Capabilities (GMTI)
- Interferometric SAR
    - 3D Imaging
    - Battle Damage Assessment
    - Target Identification
- Absolute Geo-Location
- Improved Imaging Techniques

*current development areas

Comm/EW Suite Modular Mission Payload

CONCEPT DESCRIPTION

- Real time specific emitter/platform ID & precise geo-location
- Sensor fusion of RF and EO/IR signal processing for Comm/ESM/MWS into one MMP
- Lightweight EO/IR MWS sensor
- Lightweight, short duration towed IR flares/RF decoys
- Real time sensor cueing for shooter, GCS, RCS

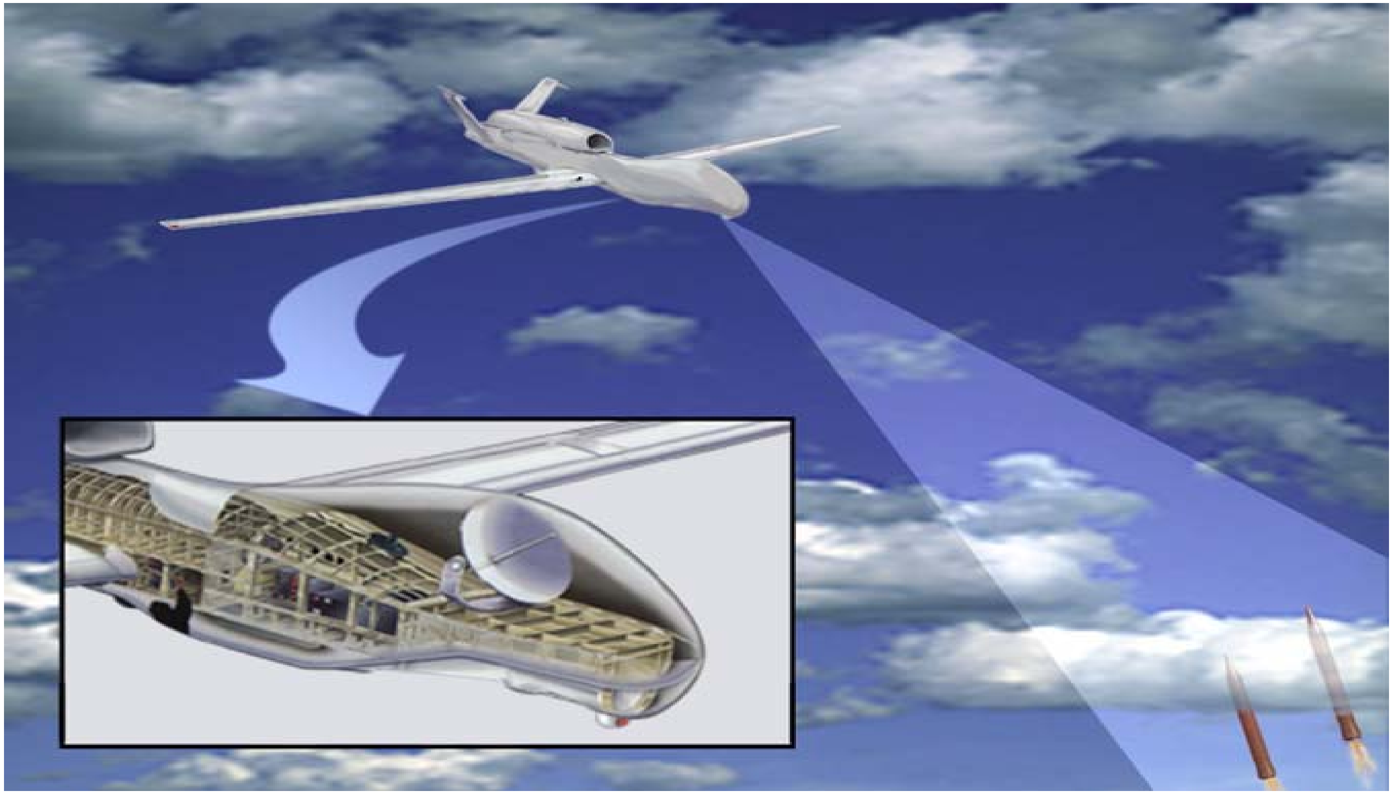
REQUIREMENTS/NEEDS

- Specific threat RF emitter identification & location
- Compact, low power, lightweight
- Integrated RF Comm/ESM/ECM/MWS mission payload
- Long range combat ID
- Lightweight, compact RF/IR towed decoys
- Comm intercept/relay
- Lightweight, compact EO/IR MWS sensor

BENEFITS

- Passive emitter targeting/sensor-to-shooter cueing
- Minimize fratricide
- Characterize battlespace/deconfliction
- Increase reaction time
- OTH Comm relay for SAR/FAC
- Improved situational awareness
- Platform survivability

ESM for UAVs

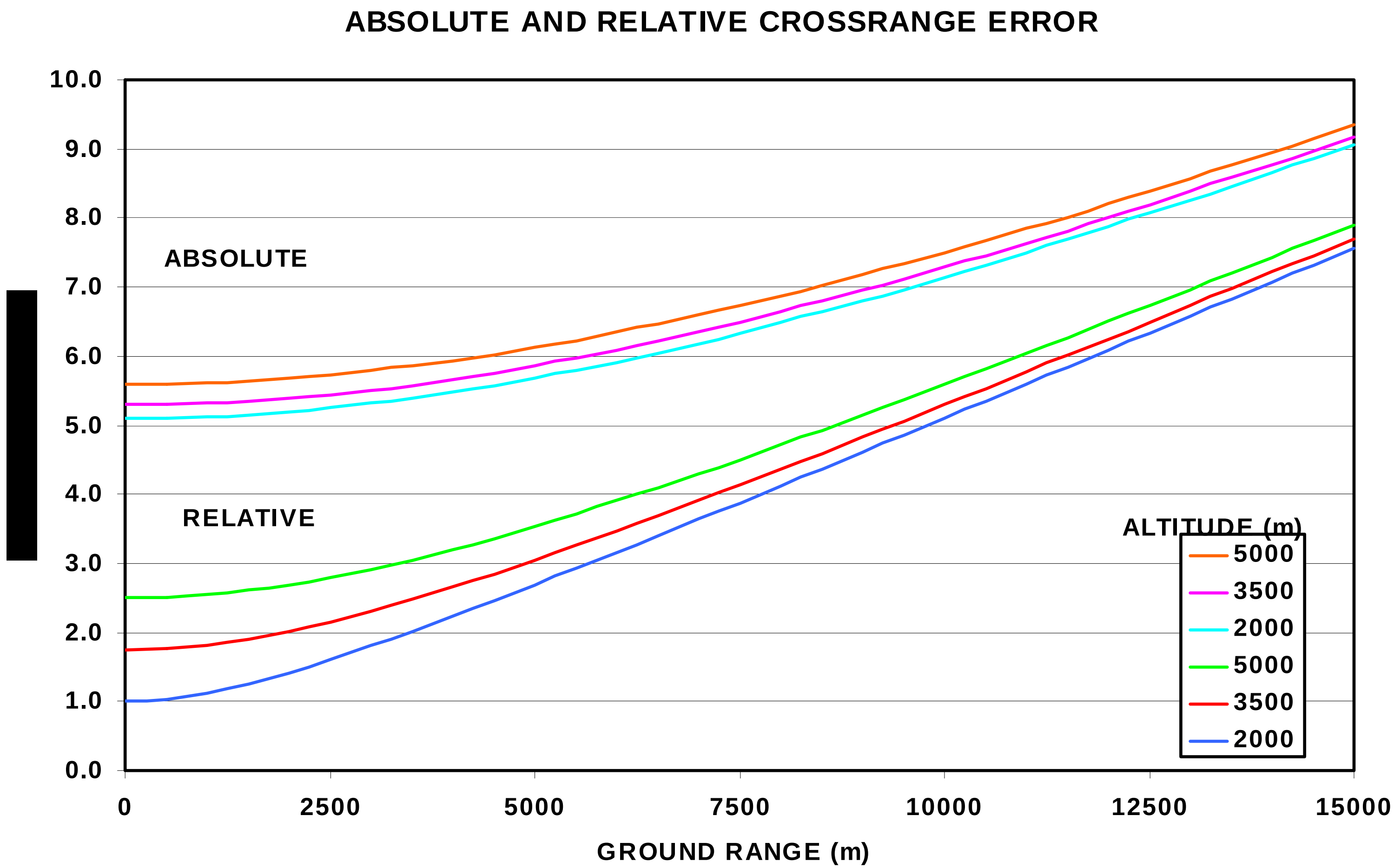


- Autonomous UAV Operation
- Cue to Emitter Bearing/Location
- Real Time Emitter/Platform ID
- <35 Lbs. including Antenna

Target Location Error

- **Target Location Error (TLE) model for EO/IR sensors**
  - **Relative to platform coordinates**
  - **Absolute in GPS coordinates**
- **2 Options for modeling TLE**
  - **Sensor direct observations of target**
  - **Target position relative to observation of mensurated point in scene**
- **Inputs to Model**
  - **EO system parameters**
  - **Aircraft Altitude and Slant range**
- **Outputs are plots of relative and absolute target location error with respect to range and altitude**

TLE Model Results

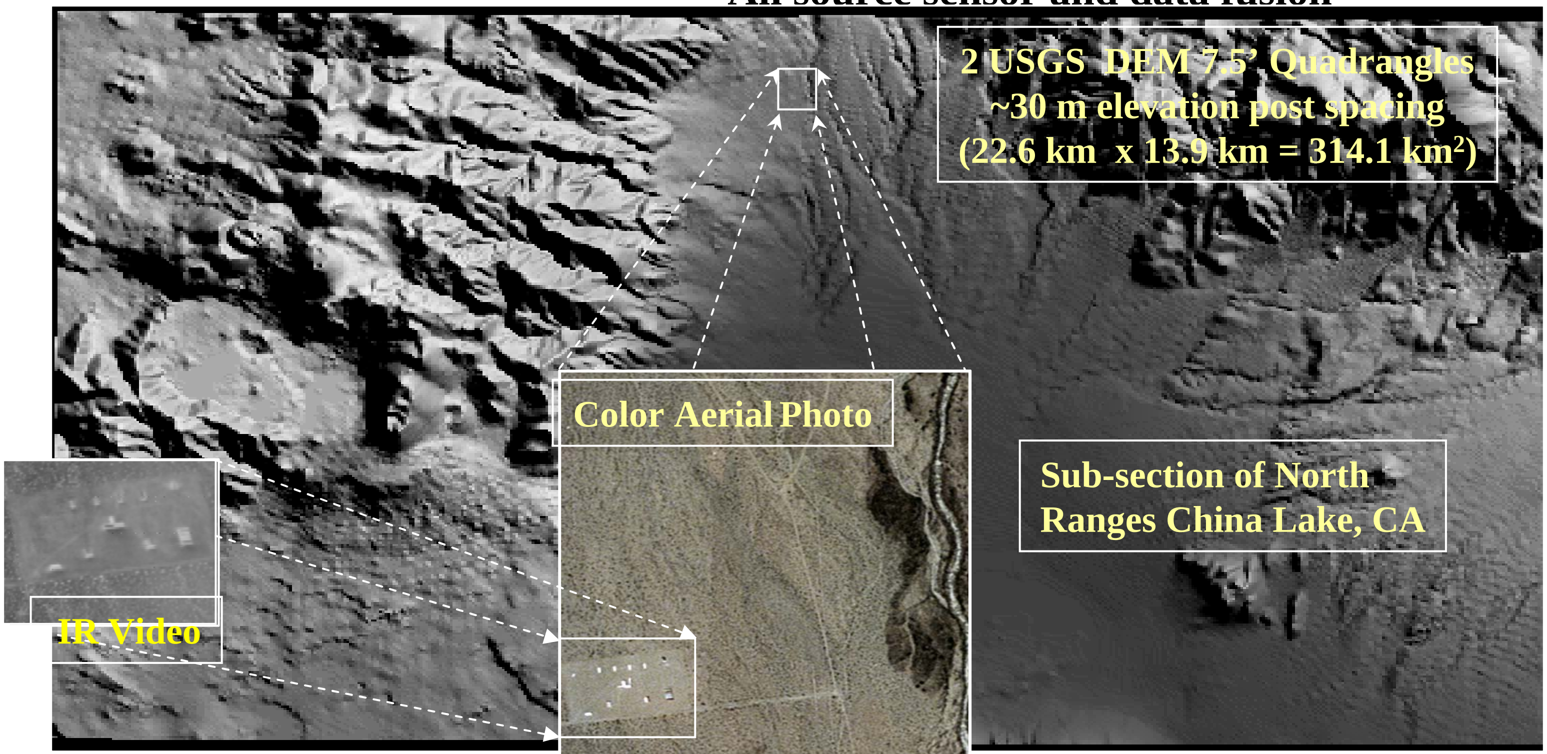


Sensor Image - Map Overlay

REQUIREMENTS/NEEDS

- Target prioritization and weapon selection and tasking: less than 10 sec. from receipt of relevant information
- Minimize target location error
- Targeting and navigation in the absence of GPS
- All source sensor and data fusion

CONCEPT DESCRIPTION



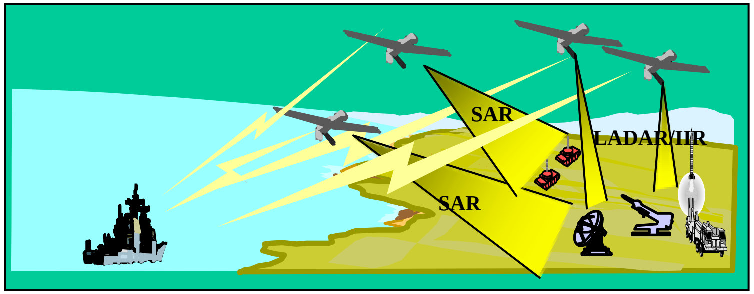
IR Video ~ 2 m/pixel Resolution (416.2 m^2); Color Aerial Photo ~ 5 m/pixel Res. (1.2 km^2); USGS DEM 30m/pixel Resolution

BENEFITS

- Replace intensive manual updating
- Enable near real time sensor archive update
- Imagery linkage for situational awareness
- Improved timelines for mission planning
- Common view of the battlespace
- Enable reach-back capability

ATR and ABDA for VTUAV

CONCEPT DESCRIPTION:



- ATR and ABDA decision aid
- Integrate SAR, LADAR, and IIR into coordinated network-centric target information source for ATR and ABDA
- Employ SAR for long-range wide-area GMTI, detection, recognition, and ABDA
- Employ IIR for limited FOV detection and recognition
- Exploit LADAR to collect close-range high-quality data for target identification
- Fully exploit HRR SAR for ATR and ABDA by analytically enhancing resolution
- Exploit unmanned platforms by tasking multiple LADAR equipped UAVs to collect close-range, narrow FOV, high quality imagery for ATR

Requirements/Needs:

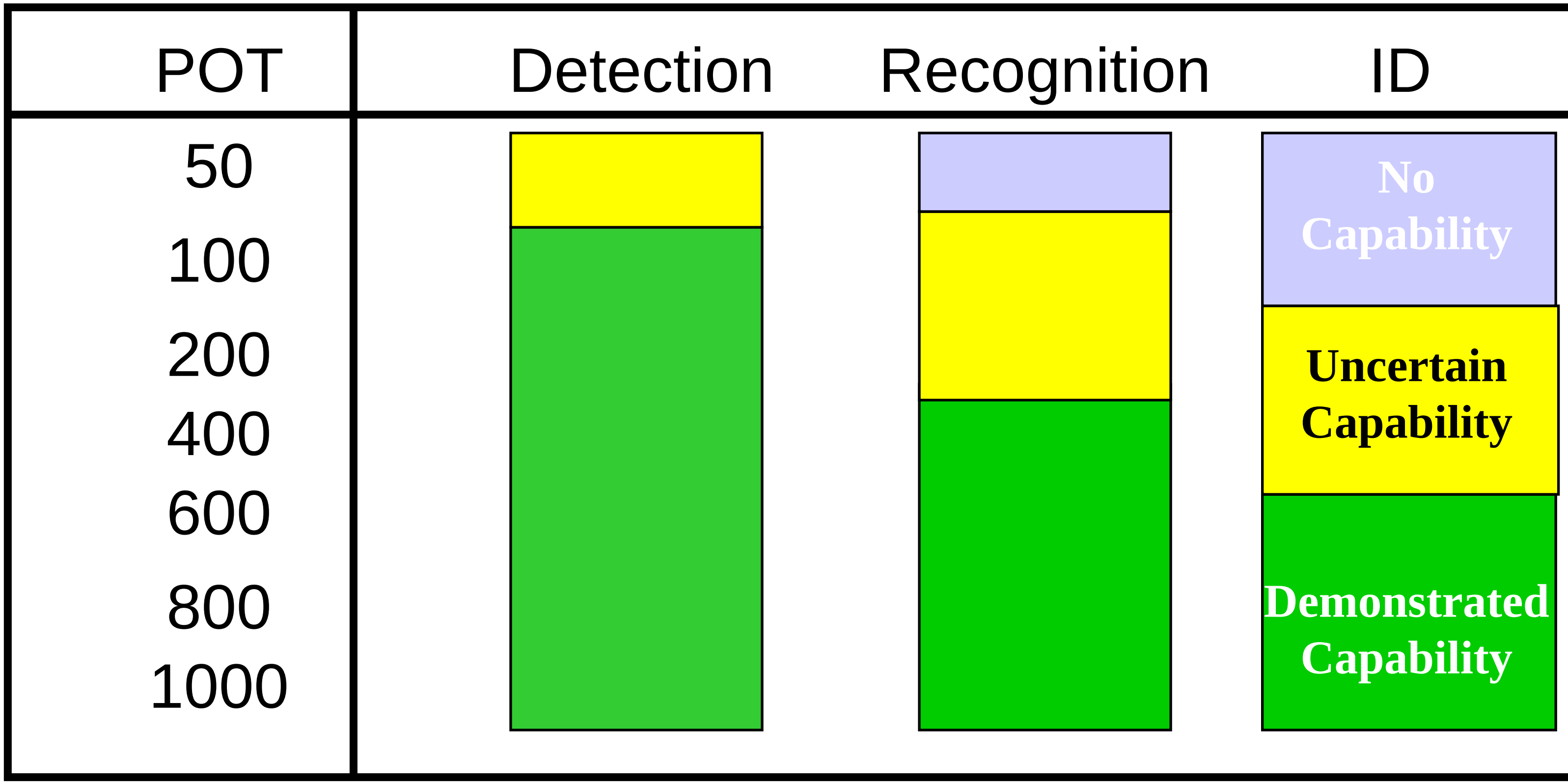
- Real-Time Detection, Identification, and Battle Damage Assessment of Moving and Stationary Mobile Targets
- Under the Following Conditions:
  - Heavy Urban and Rural Clutter
  - In-Hide Behind Trees, Terrain, Buildings
  - All-Weather

Benefits

- Improved weapon efficiency and effectiveness
- Improved op-tempo
- Reduce image analyst time to detect and declare targets < 1 min
- Reduced time to weaponeer to collateral damage constraints <1 min
- Reduced time to ascertain strike damage < 1-5 min

Current General ATR Capabilities (Applicable to all Sensors/Seekers)

Stationary Mobile Targets In-The-Clear with no Obscuration



Meaning of Demonstrated

- **Demonstrated in 6.3**
- **80% Correct Identification Rate**
- **Acceptable FAR**

- **Detection => Vehicle**
- **Recognition => Tank**
- **Identification => T-72 Tank**
- **POT => Pixels-on-Target**

UAV SENSOR PAYLOAD STUDY

SUMMARY OF CAPABILITIES

- EO/IR TECHNOLOGY
  - EO/IR/TV
  - MULTI/HYPERSPECTRAL IR
- LIDAR TECHNOLOGY
  - POLLUTION MONITORING
  - CHEM/BIO AGENT DETECTION AND TRACKING
- EYESAFE 3-D LADAR TECHNOLOGY
  - OBSTACLE AVOIDANCE & TERRAIN MAPPING
  - TARGETING & FIRE CONTROL
- SAR TECHNOLOGY
  - ALL WEATHER RECONNAISANCE & SURVEILLANCE
  - SUFFICIENT RESOLUTION FOR DETECTION & RECOGNITION
- EW TECHNOLOGY
  - INTEGRATED WITH OTHER RF/IR SYSTEMS
  - SMALL MISSILE WARNING RECEIVERS
- TARGET LOCATION ERROR (TLE)
  - PRECISION NAVIGATORS versus SCENE MATCHING CORRELATION
  - PREDICTIONS FOR EO/IR SENSORS
- ATR/ABDA TECHNOLOGY
  - TARGETS IN OPEN BY 2005 (LADAR, SAR)
  - TARGETS IN HEAVY CLUTTER BY 2010 (FOPEN, UHRR SAR, IFSAR)

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